DAEDALEAN, Incorporated

COMPLETION REPORT

TECHNICAL SUPPORT ASSISTANCE FOR THE DEVELOPMENT OF A MOBILE SELFCONTAINED CLEANING SYSTEM FOR UNDERWATER USE

Submitted to:

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1.0 PROGRAM BACKGROUND

Under the direct sponsorship of the U. S. Geological Survey (USGS) of the Department of the Interior, an Experimental Autonomous Vehicle Program (EAVE) has been under active development at both the University of New Hampshire and the Naval Ocean Systems Center, San Diego, California. The goal of the program is the development of the technology for unmanned free swimming vehicles capable of performing inspection tasks on underwater pipelines and offshore structures. Both vehicles have been developed to the point where prototype hardware can be attached and demonstrate useful forms of work.

This project is devoted to the development of specific tooling technology whereby the vehicle can be utilized to clean and inspect welded structural joints. The tooling must be capable of removing fouling from structures for the purpose of either visual inspection or the application of some sort of nondestructive testing device. This operational capability must be selfcontained on the vehicle and the vehicle must be able to maintain station during the cleaning operation and compensate for any thrust forces generated as a result of the cleaning operation.

DAEDALEAN, Incorporated was funded jointly by the USGS and the Office of Naval Research (ONR) to demonstrate that the cavitation erosion phenomena could be used to accomplish the cleaning objectives of the program.

The program was further divided into three phases:

PHASE I - Basic feasibility analysis and breadboard design of the miniaturized system.

PHASE II - The engineering, and laboratory testing of the CONCAVER™ nozzle cleaning system.

PHASE III - Integrate the prototype cleaning system on the EAVE's vehicle for a practical demonstration.

PHASE I of the program was successfully carried out with a completion report forwarded in December 1982.

PHASE II of the program was modified due to funding constraints and the results of the technical meeting of all parties at the University of New Hampshire and documented on the completion report dated December 1982. In June 1983, DAEDALEAN, Incorporated (DAI) received a purchase order from Naval Surface Weapons Center, White Oak to provide technical assistance for PHASE II.

The balance of this report outlines the engineering and lab testing accomplished during PHASE II.

2.0 PHASE II - TECHNICAL SERVICE SUPPORT

DAI engineers conducted laboratory testing of several types of CONCAVER nozzle tip assemblies to identify the nozzle design most suited to use on the EAVES vehicle for the removing of fouling, rust, scale, and paint from a target surface. With the proper nozzle design selected, the high pressure water would be delivered by the lithium gas generator developed independently by the U. S. Navy. The problems associated with this arrangement were:

(a) Correct nozzle design

(b) Triggering mechanism

(c) Maintaining vehicle station during work

(d) Identifying safety controls to protect "EAVES" vehicle and personnel during installation, testing and deployment.

2.1 Nozzle Testing

The standard DAI CONCAVER nozzles for accomplishing this type of work have a nominal standoff distance of approximately 3/4 inch. This limitation had a severe impact on the ability of the EAVES vehicle to maintain a steady position on station during the actual work cycle. Standard nozzles for this work are primarily of the straight jet configuration and would cover only a minimum amount of surface area during the 30 second work period.

A series of tests were conducted using various nozzle tip configurations, most had the same dissappointing results. Even if the EAVES vehicle could "pan and tilt" while maintaining station, the resultant work would give the appearance of a 1/4 inch side cleaned area in a disjointed pattern.

The test plates used for nozzle testing were 12 inch square and painted with 8-10 mils of antifouling paint. Standoff distance was varied from 1/4 inch to 2 1/4 inches. Pan and tilt action was simulated during some of the tests by means of a hand operated swivel device. The high pressure water source was furnished by a diesel powered Aqua-Dyne pump at 10,000 psi and 10 gpm. Short operating bursts were made ranging from 20 seconds to 1 minute. Pressure variances during these short work periods could not be adequately controlled to simulate pressure ranges that could be anticipated from a lithium gas generator.

Fan type nozzle tips produced a wider work path, approximately 1 inch, but were also found to be more critical with regard to standoff distances. For example, a 30 second work cycle with two simulated pan and tilt actions at 10,000 psi, and standoff distance of 2 inches, did not remove any of the painted surface to bare steel.

Just prior to this testing, in May 1983, DAI developed a new type experimental nozzle tip assembly, while conducting some inhouse research. Although the testing data was very limited, it was decided to try this new type nozzle for the "EAVES" project. The exact configuration of the nozzle tip assembly is proprietary to DAI, but the results of the testing were very significant.

The initial tests were conducted in the same manner as used with the standard nozzles. The work area (path cleaned by the nozzle tip) was basically the same as the standard nozzles, even with 2 1/4 inches standoff the nozzle would clean the paint from the target plate to bare steel. Further experiments were conducted lengthening the standoff distance, but keeping all other conditions the same. It was found that under these conditions a 10-1/2 inches standoff distance could be tolerated and still have effective removal of the paint.

Further testing proved consistently that a work standoff range of 1/2 inch to 10 inches could be used and achieve equal work results. The cavitation envelope created by the new type nozzle is shaped like a long thin cigar, and at any point over the length of the envelope equal work can be produced.

The importance of this testing is very significant to the objectives of the "EAVES" development program. Station keeping of the vehicle, with relationship to the target plate, is no longer the critical operating parameter that was encountered initially in PHASE I or the early testing in PHASE II.

With a variable standoff distance becoming an acceptable parameter, it is envisioned that this type of tool would be capable of cleaning weldment areas of all types of fouling, rust, scale and paint to permit inspection for cracks or deep pitting.

It should be noted however, that testing of this new type nozzle has been very limited due to the limited effort available for DAI engineering and testing in this phase of the program. DAI engineers are continuing to research the phenomena of cavitation with the new type nozzle under an in-house research program. The development of a fan jet with a variable standoff distance and equal work capability within an expanded work range would be a highly desirable breakthrough with the technology. Unfortunately, funding for in-house research is very limited and progress has been slow.

2.2 Triggering Mechanism and Other Support Work

A working model of the lithium gas generator being developed by the Navy has not been completed or available for testing. Therefore, the detailed engineering and selection of a triggering mechanism could not be accomplished. DAI engineers have investigated several candidate triggering devices. The triggering device ultimately selected is a critical component for the success of this program. When the EAVES vehicle is "on station" at the target plate, the triggering device will activate the lithium gas generator which produces the high pressure water to the cavitating nozzle. A premature activation would result in the nozzle discharge missing the target plate.

One candidate system designed by DAI would use a probe attached to the nozzle array which would contact the target plate, the movement of the probe would activate a small CO_2 cylinder which would rupture the safety disc in the water inlet side of the gas generator. While this candidate system would be an effective triggering mechanism, it would be very sensitive to premature activation due to the probe coming in contact with any object other than the target plate and could pose a safety problem for personnel.

An electricl device that could be programmed by the computer that could only be activated when it is known that the probe is in contact with the target plate would appear to be a safer, more reliable candidate system to pursue. More information on the operation of the lithium gas generator and computer capability would have to be evaluted before such a triggering device could be designed.

A third candidate system investigated utilized a spring loaded device attached to a probe on the nozzle array. Although workable, it had the same inherent restrictions as the CO_2 system described earlier.

Safety controls for the nozzle array are not a necessary consideration for the system. The discharge line from the lithium gas generator, the nozzle tube and tip assembly are constructed from material that can withstand pressures of 40,000 to 60,000 psi and the maximum pressure anticipated from the generator is not expected to exceed 10,000 psi during the work cycle. Safety controls for the gas generator and the triggering mechanism are important considerations but cannot be properly addressed until a final configuration and working model of the gas generator is available. DAI engineers have experimented with various size rupture discs that could be used between the lithium pellets and the water. Candidate discs have been identified that have consistent rupture capabilities at specific pressures.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The work effort described within this completion report for PHASE II was a limited effort due to budgetary constraints, however the significance of the engineering and technical support produced by DAI far exceeded expectations. The most productive conclusions are:

(a) Using the new experimental design nozzle tip assembly, "EAVES" vehicle standoff distance from the target plate is no longer a critical consideration.

(b) The new nozzle tip would provide an excellent working tool for the cleaning and inspection of weldment areas.

(c) A simplified triggering mechanism can be used for the activation of the lithium gas generator.

(d) Safety features inherent in the nozzle array and feeder tube are satisfactory as designed.

It is recommended that PHASE III of the program be expanded from original concepts to cover initiatives that were not sufficiently funded during PHASE II. Particularly the testing of a working model of the gas generator with the CONCAVER system and the hardware development of a suitable triggering mechanism. Further, that some development time be included that will allow DAI to pursue the improvement of a fan jet type nozzle assembly that would have the capability of doing equal work over an expanded standoff range.

Due to the broad concepts of these conclusions and recommendations and the split responsibilities of the Navy, University of New Hampshire and DAI an estimated budget cannot be provided at this time. For this reason it is recommended that a joint meeting with all parties and the program sponsor be held to evaluate all the aspects of the program and the most advantageous path to pursue to bring this program to a successful conclusion.

The objectives originally sought by the program are obtainable and within reach. The "EAVE" vehicle is not a toy or an advanced technological piece of machinery that is ahead of its time. It can prove to be a very workable, productive tool whose capabilities can be cost effective and practical today. The ground gained since the inception of this program should not be allowed to become stalemated or held in abeyance, but should be rigorously pursued to a successful conclusion.